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BARIUM FELDSPARS FROM FRANKLIN, NEW JERSEY[1]

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ABSTRACT

Celsian, hyalophane and barian varieties of both microcline and anorthoclase have been identified in a silicate skarn zone at Franklin. Chemical analyses with optical and x-ray powder data are given for hyalophanes with Cn 18 and Cn 32 and for celsian with Cn 52. The microcline and anorthoclase in general contain much less Ba and are formed earlier than the monoclinic hyalophane.

This note draws attention to barium feldspars that have been found abundantly in silicate skarn at Franklin. Their occurrence was first recognized by Bauer and Palache (1926) and Palache (1937), who reported analyses, cited in Table 1, of three specimens found on an old waste heap of the Parker shaft. A later unpublished analysis also has been included in the Table. During the closing of the Franklin mine in 1952–54, supporting ore pillars were removed from the Parker shaft area, and large amounts of feldspathic skarn were obtained. The skarn zone was described as a bed-like body in the ore that ran parallel to the hanging wall of the west limb of the synclinal ore body. The skarn minerals include calcite, andradite, hendricksite, bustamite, aegirine-augite, franklinite and willemite with small amounts of hardystonite, axinite, lead silicates and other species.

A group of 59 feldspar specimens were analyzed semi-quantitatively for Ba, Sr and Pb by x-ray fluorescence analysis, with accompanying examination by optical and x-ray powder diffraction methods. Complete chemical analyses were also obtained of three specimens. The BaO content of the 59 specimens ranged up to approximately 25 per cent, as follows (number of specimens in parentheses): below 0.1 (4), 0.1 to 5 (38), 5 to 10 (9), 10 to 15 (3), 15 to 25 (3). Several different barium feldspars were recognized, which may be conveniently discussed in two main groups.

Hyalophane and Celsian. About one-third of the specimens gave an x-ray powder diffraction pattern of the adularia type, although with variation in line intensities, apparently gradational in character, especially in material high in Ba. The Ba content ranged from 0.3 to about 25 weight per cent BaO. Most specimens contained more than 3 per cent BaO. Chemical analyses, optical data and x-ray powder spacings are given in Tables 2 and 3 for three specimens which correspond to Cn 18, Cn 32 and

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TABLE 1. OLD ANALYSES OF SKARN FELDSPARS FROM FRANKLIN

	1.	2.	3.	4.
SiO_2	64.61	62.33	52.34	49.51
Al_2O_3	17.75	20.94	19.35	25.48
Fe_2O_3	0.70	1.20		
MnO		0.97	0.91	
MgO	0.56	1.25	0.54	
CaO	0.31	0.46	6.24	
BaO		1.34	6.05	11.47
K_2O	13.68	2.80	10.43	9.98
Na_2O	2.24	9.06	1.02	3.50
Rem.		0.37	2.85	
Total	99.98	100.72	99.83	100.00
S.G.				2.90

1. Microcline. Perthitic, but otherwise quite pure. Green. G. R. Durland, analyst, New Jersey Zinc Co., 1953. Ba not determined, but present.
2. Anorthoclase. L. H. Bauer and D. Jenkins, analysts, cited by Palache (1937). Rem. is SO_3, present as barite; sample probably otherwise impure. Microcline-type x-ray powder pattern. Shows grid twinning, with α 1.522, β 1.525, γ 1.529, 2V about 80° (H. Berman).
3. Hyalophane. Greyish white. L. H. Bauer and D. Jenkins, analysts, cited by Palache (1937). Rem. is SO_3 1.02, ZnO 1.00, FeO 0.77, H_2O 0.16. Optics: α 1.525, β 1.528, γ 1.530, 2V large (H. Berman). Adularia-type x-ray powder pattern. The specimen is impure, with variable indices of refraction, and this analysis, of interest because of the high Ca content, is very questionable.
4. Hyalophane. Reddish brown. Bauer and Palache (1926). Recalculated to 100 after deducting 25.08 per cent of impurities. Adularia-type x-ray powder pattern. Optically has 2V large, β about 1.54. Vermaas (1953) found Ca present, with optics corresponding to Cn 24.

Cn 52. The content of BaO deduced either from the β index of refraction by the graphical method of Roy (1965) or from the interplanar spacing of (132) by the graphical method of Gay (1965) is in reasonably good agreement with the chemical values.

The barium feldspars of this type at Franklin range in color from white and creamy white to pale brown, with a vitreous to somewhat pearly luster. In thin section they are commonly turbid from minute inclusions or are veined by foreign material along cracks and cleavages especially in types high in Ba. The heterogeneous nature of seemingly pure masses is clearly revealed by examination in ultraviolet radiation. All occur as anhedral grains up to 2 or 3 cm in size and as granular aggregates. Specimens several pounds in weight consisting almost wholly of hyalophane were observed. The celsian of analysis 3 has somewhat variable indices of refraction because of zoning, with α mostly between 1.558 and 1.564 and

birefringence about 0.005. The optical orientation is the same as in hyalophane, with the obtuse bisectrix γ parallel to [010]. The axial angle $2V_\alpha$ of this and of the two other analyzed specimens is large and somewhat variable.

The crystal structure of celsian proper (near the end-composition $BaAl_2Si_2O_8$) is similar to that of adularia and of the series of barian feldspars extending therefrom through hyalophane, but with different SiAl ordering and with doubled c (Newnham and Megaw, 1960; Jones and Taylor, 1961; Taylor *et al.*, 1934). The position of the structural discontinuity or transition in this chemical series, possibly represented by a solubility gap, is not yet clearly established. The effects on this discontinuity of thermal history and of the presence of additional cations such as Ca, Na and Fe^{3+} in solid solution are not known either. A discontinuity of unknown significance has been placed by Yoshimura (1939) and Vermaas (1953) between about Cn 37 and Cn 50. Gay (1965) has established that c is doubled in compositions above Cn 70, and there is a dis-

TABLE 2. NEW ANALYSES OF FELDSPARS FROM FRANKLIN

	1.	2.	3.
SiO_2	55.80	50.17	42.54
Al_2O_3	20.67	22.76	24.56
Fe_2O_3	0.21	0.15	0.10
MnO	0.11	0.32	0.34
MgO	0.05	0.05	0.10
CaO	1.72	1.33	3.10
BaO	9.23	15.67	24.18
PbO	0.25	0.07	0.11
SrO	0.10	0.10	0.05
K_2O	10.45	8.51	4.22
Na_2O	0.66	0.19	0.20
H_2O	0.90	0.98	1.04
Total	100.15	100.30	100.54
S.G.	2.71	2.80	3.02
α	1.529	1.541	1.558–1.564
β	1.532	1.545	
γ	1.535	1.547	
Cn	18	32	52

Analyses 1 and 2 hyalophane, 3 celsian. J. Ito, analyst. Samples carefully cleaned by heavy liquids, but still slightly turbid under the microscope. Indices of refraction ± 0.001. Formulas calculated to 8 oxygens (H_2O neglected):

1. $(K_{.66}Ba_{.18}Ca_{.09}Na_{.06}Mn\ Mg\ Sr\ Pb)_{1.01}(Si_{2.77}Al_{1.21}Fe^{3+}_{.008})_{3.99}O_8$
2. $(K_{.56}Ba_{.32}Ca_{.07}Na_{.02}Mn\ Mg\ Sr\ Pb)_{0.99}(Si_{2.60}Al_{1.39}Fe^{3+}_{.006})_{4.00}O_8$
3. $(Ba_{.52}K_{.30}Ca_{.18}Na_{.02}Mn\ Mg\ Sr\ Pb)_{1.05}(Si_{2.35}Al_{1.60}Fe^{3+}_{.006})_{3.96}O_8$

TABLE 3. *X*-RAY POWDER DIFFRACTION DATA FOR HYALOPHANE AND CELSIAN

Data for analyzed material of Table 2. Cu radiation, Ni filter, Å. Pressed mounts, Si internal standard, 1°/min. scanning speed. Spacings for (132) from ¼/min. scanning speed with the SiKα_1 (111) peak as calibration. Relative intensities in arbitrary chart units.

hkl	Hyalophane Anal. 1		Hyalophane Anal. 2		Celsian Anal. 3	
	I	*d*	I	*d*	I	*d*
002, 020	5	6.51	8	6.50	29	6.54
022	6	4.59	13	4.60	12	4.62
$\bar{2}02$	12	4.21	7	4.23	4	4.24
200	5	3.867	8	3.873	14	3.900
130	45	3.771	40	3.784	50	3.802
$\bar{1}32$	8	3.616	9	3.620	14	3.633
$\bar{2}22$	5	3.540	8	3.542	18	3.562
$\bar{1}14$	35	3.467	36	3.467	36	3.480
220	42	3.316	68	3.324	100	3.344
	19	3.284	29	3.284	23	3.286
004, 040	100	3.239	100	3.244	60	3.258
132	35	2.998	45	3.006	49	3.011
024, 042	20	2.903	27	2.912	26	2.918
$\bar{1}34$	14	2.765	17	2.770	18	2.777
	7	2.601	9	2.601	10	2.607
114, $\bar{2}42$	17	2.575	24	2.580	35	2.585
	15	2.556	19	2.564		
240	4	2.522	9	2.530	12	2.540
$\bar{1}52$	4	2.417	5	2.421	15	2.430
	7	2.384	4	2.390	4	2.398
$\bar{1}16$	7	2.326	9	2.324	9	2.332
152	4	2.205	7	2.211	8	2.217
060, 006	16	2.169	29	2.171	52	2.178
	35	1.917	13	1.922	6	1.936
	15	1.800	26	1.802	15	1.804

Numerous weak or diffuse reflections omitted.

continuity in the extinction angle $\alpha \wedge 100$ on (010) and in the density at about this point (Roy, 1965). The present material with Cn 52 did not show evidence of a doubled value for *c* in a strongly exposed *x*-ray rotation photograph. This material is close in composition to the so-called celsian with Cn 50 and Cn 55 from Otjosondu, South West Africa (Vermaas, 1953) and to a so-called celsian with Cn$\sim$50 from the Kaso mine, Japan (Yoshimura, 1939). *X*-ray single-crystal data are lacking for these minerals. Pending further clarification of the structural and compositional variations in the barium feldspars in general, material with over Cn 50 is here provisionally called celsian.

Barian Anorthoclase and Microcline. About two-thirds of the specimens examined showed grid twinning under the microscope, usually on a fine scale, and afforded *x*-ray powder patterns of microcline type. These

varied widely in detail. The Ba content of the specimens ranged from virtually nil up to about 3 per cent BaO, and in general was much less than in the adularia-type feldspars from the same occurrence. Both normal microcline and highly sodian anorthoclase are represented among these feldspars (Table 1), and the variations in the x-ray patterns, chiefly in relative line intensities, doubtless reflect variations in the K:Na and (K,Na):Ba ratios. The indices of refraction also are variable, but with α not exceeding 1.530.

The color of the microcline-type feldspars ranges from yellowish white to pale olive green and bright green. The green material sometimes is euhedral when embedded in calcite (*cf.* Figs. 71 and 72, Palache, 1937). Quartz, extremely rare in the skarn zones at Franklin, was observed only in immediate association with microcline and anorthoclase.

Two potash feldspars were observed in immediate association in several instances. These were green microcline or anorthoclase low in Ba, and colorless or white hyalophane high in Ba. Some thin sections showed hyalophane crystals with cores exhibiting grid twinning and with considerably lower indices of refraction. The presence of the relatively large Ba ion in amounts over a certain limit apparently stabilizes the monoclinic structure in this material.

Sr was present in most specimens of both the adularia and microcline types of feldspar up to about 0.1 per cent SrO. It tended to increase with the Ba content. Pb was present erratically, usually below 0.1 per cent PbO but with up to 0.4 per cent PbO in a few specimens. Pb is well known to substitute for K in feldspar, with 0.81 per cent PbO reported in potash feldspar from Idaho (Cannon, 1958), and lead feldspar has been synthesized. The Pb in the present material, however, probably is in part at least associated with inclusions of native lead and of lead silicates. Macroscopic amounts of margarosanite, barysilite and clinohedrite were observed on some feldspar specimens. The lead silicates are formed later than the feldspars. Both Sr and Pb occur in solid solution in other skarn silicates, notably in the olivine hancockite.

Albite and anorthite have been identified at Franklin, but they occur in the marble outside of the orebody and its skarn zones. A mineral tentatively identified as albite with anomalous features was mentioned by Larsen and Shannon (1922) as occurring with bustamite; it may have been anorthoclase. Small bodies of intrusive pegmatite occur in the nearby Pochuck gneiss, in the Franklin marble and in or near the orebody. They are later than the ore and skarn. A few specimens of plagioclase and of microcline from these pegmatites, showing an association with allanite, quartz, hornblende and zircon, were analyzed and found

to lack barium. A barian variety of microcline from Sterling Hill, N.J., was also identified in the course of this study.

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